

Integrating Models, Measures, and Visualizations of Acoustic Backscatter

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Award: N00014-00-1-0180

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LONG-TERM GOAL

The long-term goal of this program is to quantify, understand, and visualize acoustic backscatter from fish. Our strategy compares backscatter model predictions to laboratory and field measurements and integrates results in computer visualizations.

OBJECTIVES

Objectives of this project include: modeling acoustic backscatter from individual and aggregations of fish; integrating fish anatomy, behavior, ontogeny, and physiology in predictions of acoustic backscatter; comparing acoustic technologies used to quantify fish distributions and abundance; and visualizing acoustic backscatter from individual and aggregations of fish.

APPROACH

The Kirchhoff-ray mode (KRM) backscatter model is used to predict backscatter as a function of acoustic wavelength, fish length, and fish orientation (i.e. aspect and roll). Backscatter predictions for individual or groups of fish are compared to laboratory and *in situ* field measurements and used in computer visualizations to integrate results. Rick Towler leads development of computer visualizations and revisions to backscatter modeling code. Computer programming support is provided by David Chevrier on the east coast. Graduate students Elliott Hazen and Julian Burgos are developing methods to quantify the relative importance of biological factors on backscatter amplitude, and to simulate spatial and temporal distributions of pelagic fish populations.

WORK COMPLETED

We have initiated efforts to parameterize KRM backscatter amplitudes in a predictive target strength model: $TS(L, \lambda) = \beta_1 \log_{10}(L_m) + \beta_2 \log_{10}(\lambda) - \beta_3$, where L is fish length and λ is the acoustic wavelength. KRM predicted backscatter amplitudes for 25 adult walleye pollock (*Theragra*

chalcogramma) were used to estimate regression parameters β_1 , β_2 , and β_3 . The TS(L, λ) regression was compared to a KRM predicted mean walleye pollock target strength curve and to the standard target strength-to-length equation used by the Alaska Fisheries Science Center (AKFSC). Expanding the predictive model to incorporate fish orientation (tilt and roll) is under development.

A second research theme focuses on spatial and temporal distributions of fish. A book chapter was completed examining adult pelagic fish distributions in Lake Ontario. Walleye pollock distributions in the Bering Sea were used to investigate the potential for scale-dependent density distributions and to examine if fish movement biases abundance estimates in current acoustic survey designs.

Two papers and two reports were published in the last year with an additional two papers in press and six submitted. A total of 16 presentations were made individually, jointly, or in collaboration with colleagues at regional, national, and international meetings.

East coast:

Three frequency echosounder data (12, 38, and 120 kHz) were used to develop species classification algorithms for organisms in the northwest Atlantic (Gulf of Maine and Georges Bank). Collaboration with scientists at the Naval Research Laboratory provided additional low frequency data (0.5-10 kHz) to size and discriminate swimbladder-bearing from non-swimbladder bearing fish.

Alewife (*Alosa pseudoharengus*) and Atlantic herring (*Clupea harengus*) were used to test the effects of flash freezing on fish body and swimbladder shape. Prior to and after flash freezing with super-cooled ethanol, fish were radiographed in dorsal and lateral planes and digitally scanned using computer tomography (CT). We are using swimbladder metrics (*e.g.*, area, volume) and other techniques (*e.g.*, thin-plate spline, conformal mapping) to quantify changes in swimbladder shape.

West coast:

Studies examining the effects of walleye pollock anatomy, ontogeny, physiology, material properties, and behavior on acoustic backscatter have been completed. A computer-controlled tilt and depth system has been designed and tested for individual tethered fish. This system is being used to measure backscatter amplitudes and variability of walleye pollock. Changes in predicted echo amplitudes were combined in dimensionless ratios to examine the relative importance of biological (tilt, length, depth) and physical (acoustic frequency) factors on backscatter from fish. The influence of wax ester and lipid-filled swimbladders on backscatter amplitudes was investigated by modeling Orange roughy (*Hoplostethus atlanticus*) acoustic characteristics.

RESULTS

Our participation in the ICES Baltic Sea Herring Target Strength Study group resulted in backscatter model predictions for 27 Baltic Sea herring and 25 European sprat. Preliminary comparisons of KRM predictions and *in situ* 38 kHz data suggest that herring and sprat behavior (depth and orientation) may be significant sources of variability in target strength measurements.

A regression model based on KRM target strength predictions of adult walleye pollock was compared to the AKFSC target strength-to-length regression model (Figure 1). All curves are in close agreement at fish lengths greater than 38 cm. Disparity among the three data sources at fish lengths below 20 cm suggests additional modeling and measuring of juvenile walleye pollock target strength is warranted.

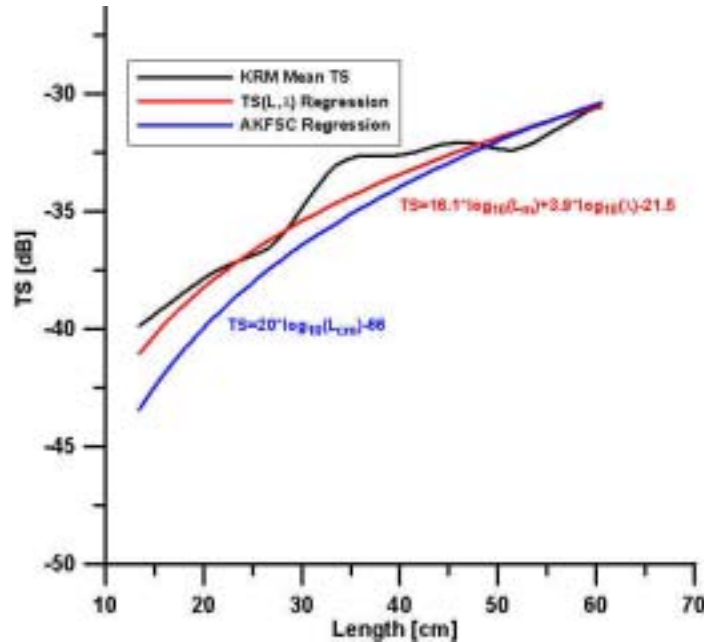


Figure 1. KRM mean target strength (TS) for 25 adult walleye pollock (black curve) at 90° dorsal incidence and 38 kHz, TS (L, λ) regression (red curve) derived from KRM predicted TS, and the Alaska Fisheries Science Center TS-length equation (blue curve).

East Coast:

Aquatic organism classification algorithms were derived using three frequency acoustic data (Figure 2). These algorithms will be verified by comparing acoustic classification to trawl catch data during survey cruises in the northwest Atlantic.

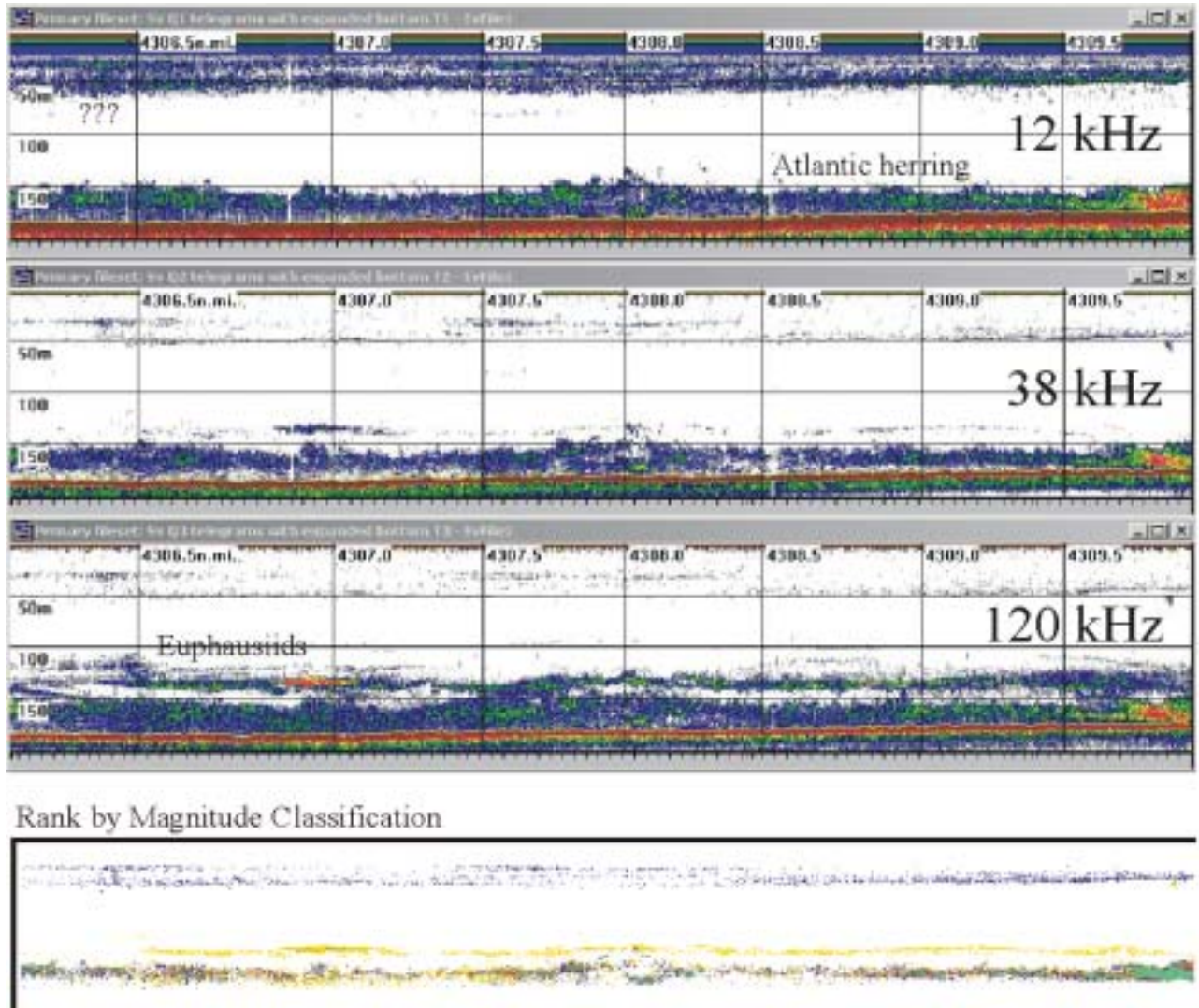


Figure 2. Data and classification echograms. The upper panel displays Simrad EK500 12, 38, and 120 kHz volume backscatter data from the northern flank of Georges Bank. The layer near the bottom in all three frequencies is Atlantic herring, the layer in the 120 kHz echogram at approximately 140 m is euphausiids, and the layer near the surface in the 12 kHz echogram is due to unknown organisms. Lower panel displays results of a generalized rank-by-magnitude algorithm.

West Coast:

Visualization of acoustic backscatter continues with the development of the echoviz application (Figure 3). A behavior simulator provides trajectories for each fish in real time. Target strengths at two frequencies and species discrimination metrics are tracked for selected individuals in single or multi-species aggregations. Utility of target discrimination metrics is explored using Boolean operators. Target strength data can be plotted using target differencing or other user-defined metrics.

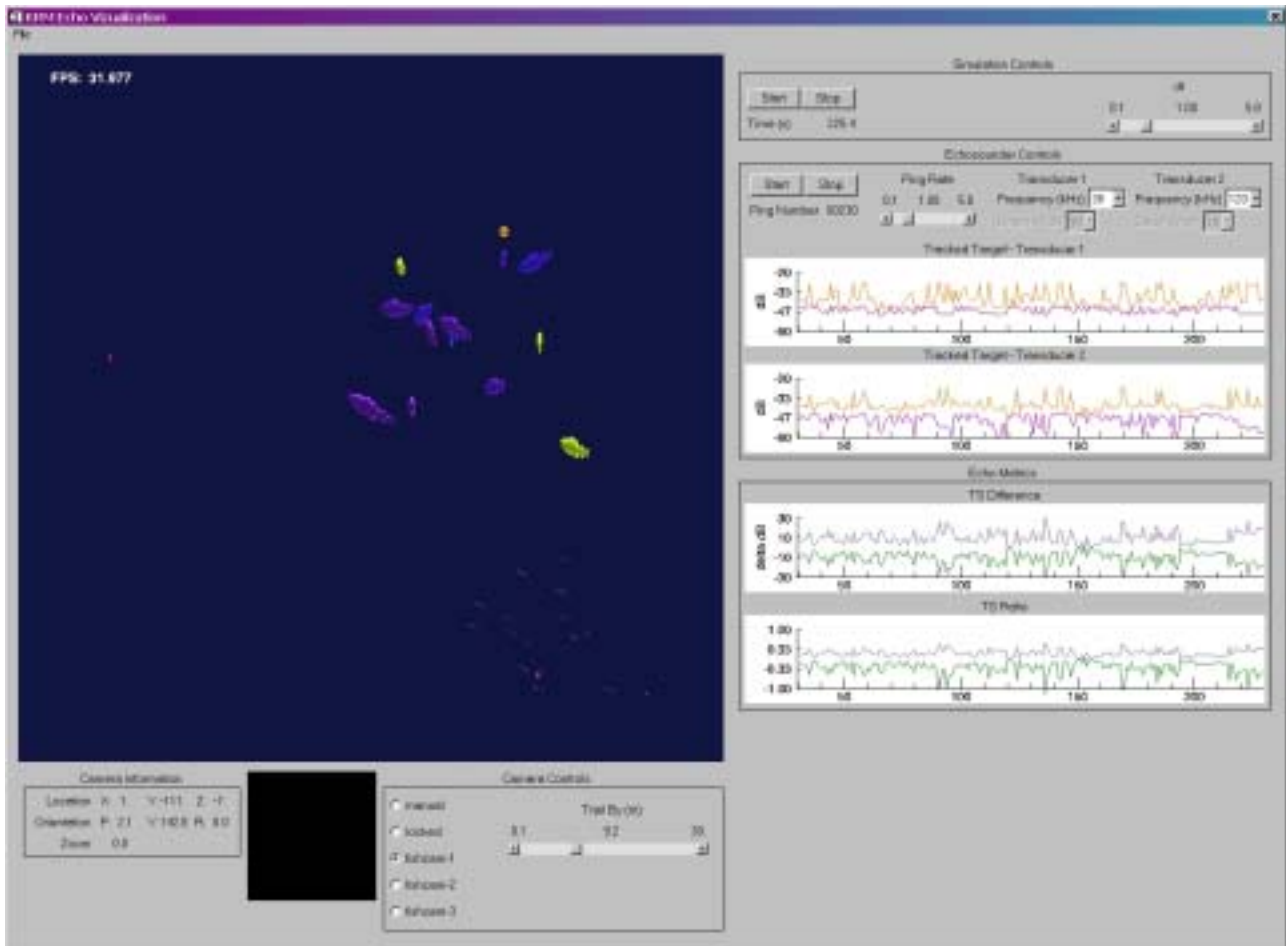


Figure 3. Screen capture of the echoviz application. The left panel displays the tracked ensemble of fish that are color coded for backscatter amplitude at 120 kHz. The right panel contains simulation controls, tracked target backscatter amplitude at 38 and 120 kHz, and target discrimination metrics.

The utility of the KRM backscatter model was increased through development of a GUI interface, extensive batch processing capability, and new modules that calculate backscatter as a function of fish depth and material properties (*i.e.*, sound speed and density contrasts).

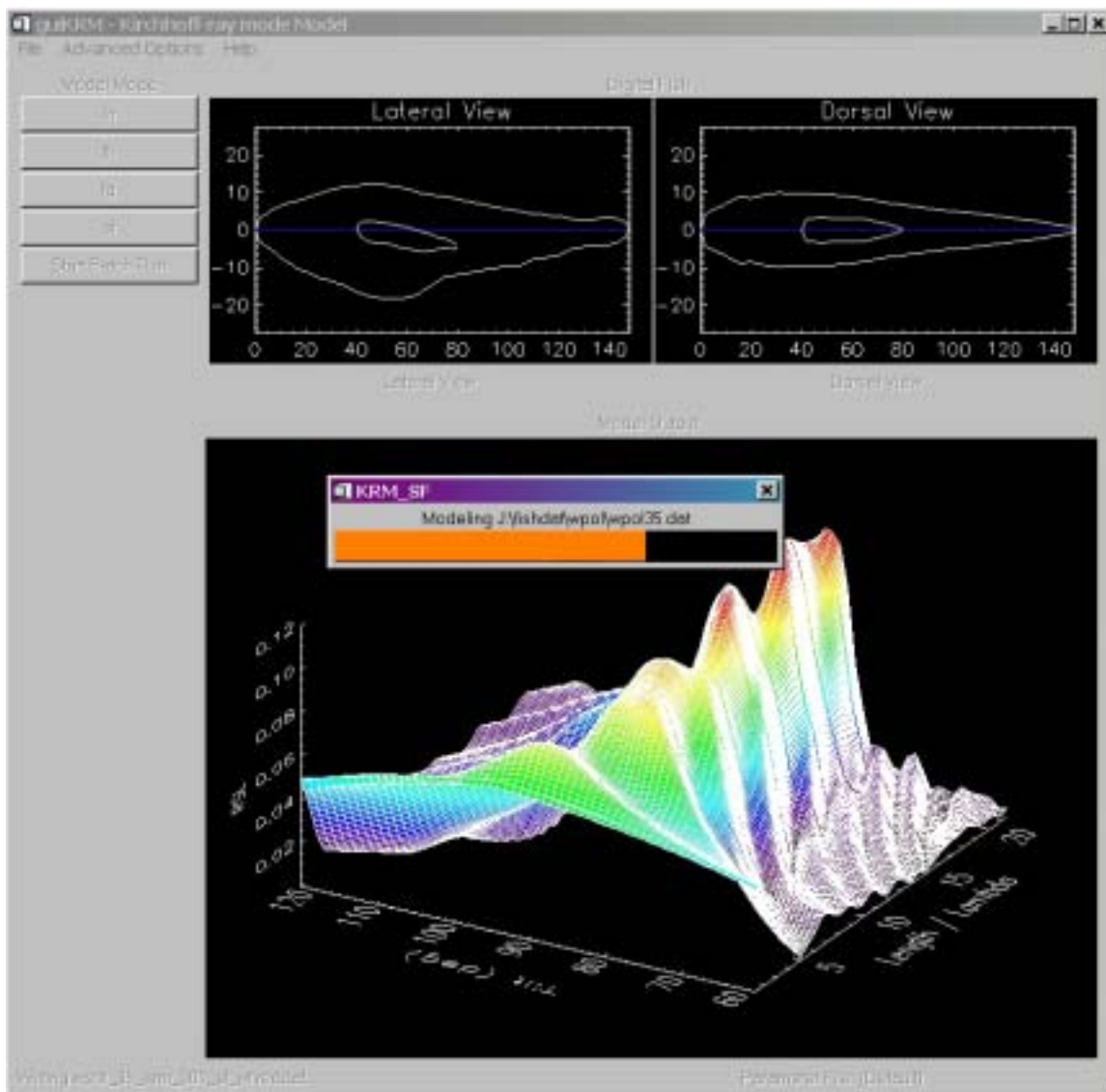


Figure 4. Screen capture of the new KRM model GUI screen showing a walleye pollock lateral (upper left) and dorsal (upper right) data file, and the backscatter response surface as a function of aspect angle and the ratio of fish length to acoustic wavelength.

IMPACT/APPLICATIONS

A generalized TS model that incorporates fish length, orientation, and acoustic frequency will improve conversions of acoustic size to fish length, and accuracy of acoustic-based abundance estimates. This model can be used in conjunction with data from traditional echosounders and can be adapted for use with multi-beam and broadband sonars.

TRANSITIONS

Scientists at the Northeast Fisheries Science Center (Mr. William Michaels, Mr. Chris Gurshin) are developing methods to collect and analyze underwater video images of fish aggregations. Acoustic

data collected in conjunction with these images will be used to incorporate fish behavior in conversions of acoustic data to fish length and abundance. Researchers in the U.S. (NOAA Fisheries) and Canada (Department of Fisheries and Oceans) are initiating collaborations to incorporate KRM backscatter predictions in multi-frequency and multi-beam measurements.

RELATED PROJECTS

Collaboration with scientists at the Woods Hole Oceanographic Institution to develop an acoustic calibration facility will improve our ability to incorporate KRM backscatter predictions in quantitative analyses of echosounder and multi-beam data. Collaboration with researchers using swimbladder resonance frequency acoustics will enhance our ability to classify and discriminate fish and invertebrate species.

The KRM backscatter model is being used to acoustically characterize ‘forage’ fish species in the Bering Sea and Gulf of Alaska. The potential to acoustically discriminate fish species in these areas will improve acoustic-based abundance estimates of all species and will be used to examine potential food resources for Steller Sea Lions (*Eumetopias jubatus*). Species discrimination combined with examination of walleye pollock spatial distributions is also being used to structure a pollock dynamics model. This model will be used as input to Steller Sea Lion foraging models. Acoustic measurements and KRM backscatter predictions are also being used to examine acoustic shadowing and extinction in Atlantic salmon (*Salmo salar*) aquaculture pens.

PUBLICATIONS

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